

345

United States Department of Agriculture
Agricultural Research Administration
Bureau of Entomology and Plant Quarantine

NICOTINE INSECTICIDES. Part V--SEARCH FOR SYNERGISTS

By E. L. Mayer and E. R. McGovran, ^{1/} Division of Control Investigations, Bureau of Entomology and Plant Quarantine, and Florence B. Talley, C. R. Smith, D. H. Saunders, and C. F. Woodward, Eastern Regional Research Laboratory, Bureau of Agricultural and Industrial Chemistry ^{2/}

This paper is the fifth in a series reporting investigations on nicotine insecticides (see E-646, E-709, E-720, and E-725). In Part II (E-709) an effort was made to find compounds that might replace part of the nicotine to stretch the limited supply of this insecticide and thereby make its use more economical. This paper is a continuation of such studies and presents results obtained with 107 additional materials. As before, all mixtures were prepared at the Eastern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry and tested against plant-feeding insects at the Sanford (Fla.) and Anaheim (Calif.) laboratories of the Bureau of Entomology and Plant Quarantine.

Some of the compounds used here have been tested alone as insecticides. Swingle, Phillips, and Gahan (7, 8) showed that phthalonitrile and 1,4-diphenylsemicarbazide were as good stomach insecticides as lead arsenate and that, in general, phthalonitrile was superior to derris and pyrethrum, with which it was also compared. Gahan, Swingle, and Phillips (2) also showed that 1,4-diphenylsemicarbazide was more toxic than lead arsenate and derris to the melonworm and the southern beet webworm, and about equal to the two materials against the Hawaiian beet webworm and the southern armyworm. Phthalonitrile (Schechter and Haller 5) and 1,4-diphenylsemicarbazide (Freeman 1) have been patented as insecticides. Läuger (3) showed that bis(p-chlorophenyl) sulfide was highly toxic to clothes moths.

1/ Now with Office of Experiment Stations.

2/ This work was conducted under the general supervision of G. T. Bottger. A. P. Yerington and Carl Robertson helped with the rearing of insects and the testing of insecticides.

Materials and Methods

In this study each sample contained 5 percent of adjunct plus only 2 percent of nicotine as the sulfate, whereas 5 percent of nicotine was used previously. All mixtures were compared with dusts containing 5 percent and 2 percent of nicotine except when used against the pea aphid, when 3.5 percent and 2 percent of nicotine were used. Most of the mixtures contained attapulgite as the diluent. This material was found to be an excellent carrier for nicotine, because of its ability to adsorb large amounts of liquid, its dustability, and its tendency to increase mortalities (E-720). Several materials were compared with each other in three carriers--attapulgite, bentonite, and pyrophyllite. As in Part II, the adjuncts were chosen at random.

Several species of lepidopterous larvae, three species of aphids, and the large milkweed bug were used as the test insects. The insects and stages used were first instars of the southern armyworm (Prodenia eridania (Cram.)) and the variegated cutworm (Peridroma margaritosa (Haw.)); third instars of the diamondback moth (Plutella maculipennis (Curt.)); fourth instars of the melonworm (Diaphania hyalinata (L.)), the Hawaiian beet webworm (Hymenia recurvalis (F.)), the armyworm (Cirphis unipuncta (Haw.)), and the beet armyworm (Laphygma exigua (Hbn.)); all stages of field-collected bean aphids (Aphis fabae Scop.) and green peach aphids (Myzus persicae (Sulz.)); and 1-day-old nymphs of the pea aphid (Macrosiphum pisi (Kltb.)); and third and fourth nymphal stages of the large milkweed bug (Oncopeltus fasciatus (Dall.)).

The testing procedures were similar to those described by Swingle (6) and in Part I of this series. The materials were tested by infesting dusted foliage with first-instar larvae in cloth-covered vials and third- and fourth-instar larvae in 9-cm. petri dishes. The aphids were dusted or sprayed directly on the plants on which they were feeding and were then confined in 16.5-cm. battery jars with cloth caps. The large milkweed bugs were dusted in 7.5-cm. crystallizing dishes covered with cloth tops. The deposits usually ranged between 100 and 200 micrograms per square centimeter. About 30 larvae, 25 nymphs of the large milkweed bug, and 40 or more aphids were used in each test. Each material was tested against from 2 to 9 species. Mortality counts on the leaf-feeding larvae and the large milkweed bug were made after 3 days and those on the aphids after 2 days.

Most of this report deals with toxicants applied as dusts. If the results showed that the mixture was worthy of further testing, phytotoxicity and spray tests were run.

Discussion of Results

Where any mixture of nicotine and adjunct (table 1, A) gave higher mortality than that given by the 5-percent nicotine standard alone (table 1, B) against two or more insect species, the adjunct was considered to be

a possible synergist of the nicotine. By this criterion the compounds given in table 1 appeared to be the most promising. This table also presents mortalities caused by dusts containing 2 percent of nicotine (C) and 5 percent of adjunct (D) when used alone, and the additive kills of these two (C + D).

On the basis of comparison with the 5-percent nicotine (column A-B), the most effective adjuncts were p-bromobenzenesulfonamide, bis(p-chlorophenyl) sulfide, 1,4-diphenylsemicarbazide, 2,3,4,5,6-pentachloroanisole, pentaerythritol diisobutyral, phenyl sulfide, phthalonitrile, and 2-stilbazole. On the basis of comparison with the additive effects (column C + D), the most effective adjuncts were bis(p-chlorophenyl) sulfide in bentonite, 2,4-dinitromesitylene, pentaerythritol diisobutyral, phthalonitrile, pentachlorocumene, and 2-stilbazole. However, comparisons cannot be made with all materials owing to lack of data. 2,4-Dinitromesitylene in combination with nicotine was better than the 5-percent nicotine against only two out of eight insects, but against the six insects in the additive effect (C + D) it appeared promising.

Whether or not a given adjunct is more toxic in itself than the 5-percent nicotine is no indication of the effect when it is mixed with nicotine. In tests against the armyworm, phthalonitrile alone gave 55 percent greater kill than nicotine, but against the pea aphid it gave 34 percent less. Synergism was definitely demonstrated against both these insects in later unpublished quantitative experiments and in McGovran et al. (4)

Phenyl sulfide when used alone was not effective against any of three species of aphids. However, in mixture with nicotine it showed possible synergism against two of the species.

Table 2 gives the results of tests against pea aphids. Where comparisons of mixture and additive kills may be made, there are eight adjuncts that show promise as synergists.

The 35 adjuncts in mixtures that were superior to nicotine against at least one insect are shown in table 3. The other 72, which were ineffective against every insect tested, are given in table 4.

Of six adjuncts related to 2,3,4,5,6-pentachloroanisole, four were effective in mixtures against the southern armyworm but not against the melonworm, and the other two were ineffective against both species. None of these materials were toxic in themselves to either the melonworm or the southern armyworm, whereas 2,3,4,5,6-pentachloroanisole was toxic to these species.

Nine adjuncts related to phthalonitrile were tested. Four were effective in mixtures against the pea aphid, and one of the four, tridecanenitrile, was also effective against the armyworm but not the diamondback moth. All others were ineffective against two insects, the pea aphid and a leaf-feeding larva.

Of three materials tested for phytotoxicity, bis(p-chlorophenyl) sulfide, 2,3,4,5,6-pentachloroanisole, and phthalonitrile--none caused

any injury to at least five kinds of plants. These materials were tested separately and also in combination with nicotine.

Since the adjuncts listed in table 1 show possible synergism, they will be subjected to more comprehensive and quantitative tests, the data from which can be calculated for synergism according to Wadley's (9) method. This has already been done in the case of phthalonitrile (McGovran, Mayer, and Talley 4) and 2,3,4,5,6-pentachloroanisole.

Literature Cited

- (1) Freeman, A. F.
1942. Insecticide. U. S. Patent 2,272,047, issued February 3.
- (2) Gahan, J. B., Swingle, M. C., and Phillips, A. M.
1941. 1,4-Diphenyl semicarbazide as an insecticide.
U. S. Bur. Ent. and Plant Quar. E-549, 11 pp.
[Processed.]
- (3) Läuger, P.
1944. Über neue, sulfogruppenhaltige Mottenschutzmittel.
Helvetica Chim. Acta (F.1) 27: 71-87.
- (4) McGovran, E. R., Mayer, E. L., and Talley, F. B.
1948. Synergistic insecticidal composition. U. S. Patent
2,449,533, issued September 14.
- (5) Schechter, M. S., and Haller, H. L. J.
1940. Insecticide. U. S. Patent 2,200,564, issued May 14.
- (6) Swingle, M. C.
1943. Exploring the insecticidal possibilities of new materials.
In Laboratory procedures in studies of the chemical control of insects, edited by F. L. Campbell and F. R. Moulton. Amer. Assoc. Adv. Sci. Pub. 20, pp. 82-84. Washington, D. C.
- (7) _____ Gahan, J. B., and Phillips, A. M.
1941. Phthalonitrile as an insecticide. U. S. Bur. Ent. and Plant Quar. E-548, 12 pp. [Processed.]
- (8) _____ Phillips, A. M., and Gahan, J. B.
1944. Preliminary tests of synthetic organic compounds as insecticides. Part I. U. S. Bur. Ent. and Plant Quar. E-621, 134 pp. [Processed.]
- (9) Wadley, F. M.
1945. The evidence required to show synergistic action of insecticides and a short cut in analysis. U. S. Bur. Ent. and Plant Quar. ET-223, 6 pp. [Processed.]

Table I. - Mortality data on the 15 compounds that show promise of synergism with nicotine.

| Adjunct and insect (diluent attapulgite unless otherwise indicated) | Deposit of dust, micrograms per square centimeter | Extent of feeding | | Mortality (percent) | | | | |
|---|---|-------------------------|-----|---------------------|----------------|------------------|--------------------|--|
| | | | | Mixture | Nicotine alone | Adjunct alone | Additive effect | Above or below 5 percent nicotine (A-B) |
| | | | (A) | (B) | (C) | (D) | (C+D) | |
| <u>p</u> -Bromobenzene sulfonamide: | | | | | | | | |
| Armyworm (3) ^{2/} | 107 | Trace | 75 | 39 | 14 | 64 | 78 | +36 |
| Diamondback moth | 140 | --do-- | 43 | 88 | 70 | 73 | 143 | -45 |
| Green peach aphid | 170 | - | 16 | 83 | 19 | 0 | 19 | -67 |
| Melonworm (2) | 100 | Moderate | 69 | 64 | 1/ | - | - | + 5 |
| Pea aphid | 100 | - | 73 | 82 | 81 | 0 | 81 | - 9 |
| Southern armyworm (2) | 100 | Trace | 73 | 39 | - | - | - | +34 |
| Variegated cutworm (2) | 198 | --do-- | 98 | 90 | 59 | 78 | 137 | + 8 |
| Cetyl ether: | | | | | | | | |
| Armyworm | 100 | Moderate | 21 | 88 | 32 | 5 | 37 | -67 |
| Beet armyworm | 195 | --do-- | 65 | 71 | 52 | 8 | 60 | - 6 |
| Diamondback moth | 160 | --do-- | 63 | 100 | 50 | 46 | 96 | -37 |
| Green peach aphid | 170 | - | 16 | 90 | 37 | 50 | 87 | -74 |
| Melonworm | 105 | Moderate | 22 | 63 | 46 | - | - | -41 |
| Pea aphid | 100 | - | 96 | 82 | 81 | 0 | 81 | +14 |
| Southern armyworm | 100 | Trace | 100 | 92 | 76 | - | - | + 8 |
| Bis(<u>p</u> -chlorophenyl) sulfide in pyrophyllite: | | | | | | | | |
| Hawaiian beet webworm (2) | 143 | --do-- | 96 | 85 | 29 | 85 | 114 | +11 |
| Large milkweed bug | 125 | - | 48 | 100 | - | - | - | -52 |
| Melonworm (3) | 163 | Moderate | 42 | 45 | 18 | 8 | 26 | - 3 |
| 0.1% ^{3/} | 75 | --do-- | 86 | 59 | - | - | - | +27 |
| Southern armyworm (2) | 0.1% | None | 100 | 21 | 21 | 100 | 121 | +78 |
| | | Trace | 100 | 0 | - | - | - | +100 |

^{1/} 3.5 percent of nicotine.

^{2/} Figures in parentheses indicate number of tests if more than one.

^{3/} Figures in percent indicate the strength of nicotine in a spray test.

Table 1. - (Continued)

| Adjunct and insect (diluent attapulgite unless otherwise indicated) | Deposit of dust, micrograms per square centimeter | Extent of feeding | Mixture (A) | Mortality (percent) | | | | | | |
|---|---|-------------------------|----------------|-------------------------------------|------------------|------------------|-----------------------------|--|--|--|
| | | | | Nicotine alone: 5 percent (B) | 2 percent (C) | 5 percent (D) | Additive effect (C+D) | | | |
| Bis(p-chlorophenyl) sulfide | | | | | | | | | | |
| in bentonite: | | | | | | | | | | |
| Hawaiian beet webworm | 140 | Trace | 96 | 95 | 26 | - | + 1 | | | |
| Melonworm (3) | 150 | Moderate | 55 | 59 | 13 | 26 | - 4 | | | |
| Southern armyworm (3) | 85 | None | 100 | 39 | 28 | 0 | +61 | | | |
| Bis(p-chlorophenyl) sulfide | | | | | | | | | | |
| in attapulgite: | | | | | | | | | | |
| Hawaiian beet webworm | 155 | —do— | 100 | 67 | 36 | - | +33 | | | |
| Melonworm | 165 | Moderate | 42 | 50 | 10 | - | - 8 | | | |
| Southern armyworm | 63 | None | 100 | 41 | 37 | - | +59 | | | |
| 2-Cyclohexylcyclohexylamine: | | | | | | | | | | |
| Armyworm | 130 | Moderate | 77 | 80 | 44 | - | - 3 | | | |
| Diamondback moth | 111 | —do— | 44 | 68 | 36 | - | -24 | | | |
| Pea aphid | 95 | - | 86 | 80 | 16 | - | + 6 | | | |
| 2,4-Dinitromesitylenc: | | | | | | | | | | |
| Armyworm (2) | 108 | Moderate | 40 | 45 | 16 | 26 | 42 | | | |
| Beet armyworm | 210 | None | 100 | 89 | 23 | 76 | 99 | | | |
| Diamondback moth | 135 | Moderate | 26 | 75 | 23 | 0 | 23 | | | |
| Green peach aphid | 170 | - | 49 | 83 | 19 | 2 | -34 | | | |
| Melonworm | 200 | Moderate | 32 | 63 | 29 | - | -31 | | | |
| Pea aphid | 120 | - | 73 | 86 | 46 | 13 | 59 | | | |
| Southern armyworm (2) | 100 | None | 100 | 86 | 46 | - | +14 | | | |
| Variegated cutworm | 210 | Moderate | 61 | 97 | 55 | 7 | -36 | | | |

Table 1. - (Continued)

| Adjunct and insect (diluent attapulgite unless otherwise indicated) | Deposit of dust, micrograms per square centimeter | Extent of feeding | Mixture | Mortality (percent) | | | | Above or below 5 percent nicotine (A-B) |
|---|---|-------------------------|---------|---------------------|-----------|-----------|-------------------------------|--|
| | | | | Nicotine alone | 5 percent | 2 percent | Adjunct alone 5 percent | |
| | | | (A) | (B) | (C) | (D) | (C+D) | |
| 2,4-Dinitrophenyl 2,3,4,5,6-pentachlorophenyl ether: | | | | | | | | |
| Diamondback moth | 103 | Moderate | 0 | 60 | - | - | - | -60 |
| Melonworm (2) | 105 | -do- | 32 | 40 | 15 | 0 | 15 | - 8 |
| Pea aphid (3) | 95 | - | 40 | 47 | 29 | - | - | - 7 |
| Southern armyworm | 103 | Moderate | 88 | 82 | 65 | 36 | 101 | + 6 |
| 1,4-Diphenylsemicarbazide: | | | | | | | | |
| Armyworm (2) | 90 | -do- | 48 | 28 | 5 | 77 | 82 | +20 |
| Diamondback moth | 140 | -do- | 50 | 88 | 70 | 50 | 120 | -38 |
| Green peach aphid | 210 | - | 11 | 89 | 23 | 14 | 37 | -78 |
| Melonworm | 100 | Moderate | 77 | 33 | 5 | - | - | +44 |
| Pea aphid (2) | 100 | - | 80 | 77 | 59 | 93 | 152 | + 3 |
| Southern armyworm | 100 | Trace | 100 | 82 | 41 | - | - | +18 |
| Variegated cutworm | 200 | None | 100 | 38 | 5 | 100 | 105 | +62 |
| 2,3,4,5,6-Pentachloroanisole: | | | | | | | | |
| Diamondback moth | 100 | Trace | 88 | 60 | 0 | - | - | +28 |
| Large milkweed bug | 140 | - | 12 | 23 | - | - | - | -11 |
| Melonworm (5) | 137 | Moderate | 95 | 40 | 18 | 99 | 117 | +55 |
| Pea aphid (6) | 100 | - | 75 | 47 | 29 | - | - | +28 |
| Southern armyworm | 118 | Trace | 92 | 65 | 43 | 97 | 140 | +27 |

Table 1. - (Continued)

| Adjunct and insect (diluent attapulgite unless otherwise indicated) | Deposit of dust, micrograms per square centimeter | Extent of feeding | Mixture (A) | Mortality (percent) | | | | |
|---|---|-------------------------|----------------|---------------------|---------------------|------------------|--------------------|-----------------------------|
| | | | | Nicotine alone | | Adjunct alone | Additive effect | Above or below 5 percent |
| | | | | 5 percent (B) | 2 percent (C) | | | |
| Pentachlorocumene: | | | | | | | | |
| Armyworm | 100 | Trace | 96 | 88 | 32 | 50 | 82 | + 8 |
| | 0.1% | Moderate | 0 | 48 | 20 | 0 | 20 | -48 |
| Bean aphid | 0.0025% | - | 71 | 88 | 71 | 3 | 74 | -17 |
| Beet armyworm | 205 | Trace | 100 | 67 | 30 | 70 | 100 | +33 |
| Diamondback moth | 135 | Moderate | 32 | 75 | 23 | 0 | 23 | -43 |
| Green peach aphid | 170 | - | 5 | 83 | 19 | 0 | 19 | -78 |
| Melonworm | 115 | Moderate | 22 | 63 | 46 | - | - | -41 |
| Pea aphid | 100 | - | 63 | 86 | 46 | 35 | 81 | -23 |
| Southern armyworm | 110 | Trace | 95 | 92 | 80 | - | - | + 3 |
| Variegated cutworm | 200 | -do- | 83 | 98 | 55 | 13 | 68 | -15 |
| Pentaerythritol diisobutyral: | | | | | | | | |
| Armyworm (3) | 105 | -do- | 80 | 57 | 35 | 45 | 80 | +23 |
| | 0.1% | -do- | 87 | 70 | - | - | - | +17 |
| Beet armyworm | 200 | None | 100 | 67 | 30 | 44 | 74 | +33 |
| Diamondback moth | 155 | -do- | 96 | 100 | 50 | 26 | 76 | - 4 |
| Green peach aphid | 170 | - | 53 | 90 | 37 | 38 | 75 | -37 |
| Melonworm | 110 | Moderate | 42 | 63 | 46 | - | - | -21 |
| Pea aphid | 100 | - | 98 | 82 | 81 | 0 | 81 | +16 |
| Southern armyworm | 110 | Trace | 96 | 92 | 80 | - | - | + 4 |
| Variegated cutworm (2) | 233 | -do- | 62 | 5 | 54 | 59 | +33 | |

Table 1. - (Continued)

| Adjunct and insect (diluent attapulgite unless otherwise indicated) | Deposit of dust, micrograms per square centimeter | Extent of feeding | Mixture (A) | Mortality (percent) | | | | | Above or below 5 percent nicotine (A-B) | |
|---|---|-------------------------|----------------|---------------------|---------------------|---------------------|--------------------------------------|---------------------------|--|--|
| | | | | 5 percent (B) | Nicotine alone | | Adjunct alone 5 percent (C) | Additive effect (D) | | |
| | | | | | 5 percent (C) | 2 percent (D) | | | | |
| Phenyl sulfide: | | | | | | | | | | |
| Armyworm (3) | 98 | None | 100 | 40 | 9 | 93 | 102 | +60 | | |
| | 0.1% | --do-- | 100 | 48 | 20 | 97 | 117 | +52 | | |
| Bean aphid | 0.0025% | - | 66 | 88 | 71 | 4 | 75 | -22 | | |
| Beet armyworm | 205 | None | 100 | 89 | 23 | 100 | 123 | +11 | | |
| Diamondback moth (2) | 140 | --do-- | 95 | 55 | 38 | 59 | 97 | +40 | | |
| Green peach aphid | 165 | - | 32 | 83 | 19 | 9 | 28 | -51 | | |
| Melonworm (2) | 108 | Moderate | 40 | 58 | 30 | - | - | -18 | | |
| Pea aphid | 100 | - | 100 | 86 | 46 | 0 | 46 | +14 | | |
| Southern armyworm | 100 | None | 100 | 85 | 64 | - | - | +15 | | |
| Variegated cutworm | 200 | --do-- | 100 | 67 | 39 | 67 | 106 | +33 | | |
| Phthalonitrile: | | | | | | | | | | |
| Armyworm (3) | 80 | --do-- | 100 | 21 | 4 | 76 | 80 | +79 | | |
| | 0.1% | --do-- | 100 | 70 | - | - | - | +30 | | |
| Diamondback moth | 140 | --do-- | 100 | 75 | 23 | 39 | 62 | +25 | | |
| Green peach aphid | 200 | - | 76 | 89 | 23 | 41 | 64 | -13 | | |
| Melonworm | 100 | None | 100 | 33 | 5 | - | - | +67 | | |
| Pea aphid | 105 | - | 96 | 47 | 29 | 13 | 42 | +49 | | |
| Southern armyworm | 100 | None | 100 | 72 | 6 | - | - | +28 | | |
| Variegated cutworm (2) | 200 | --do-- | 100 | 90 | 58 | 80 | 138 | +10 | | |

Table 1. - (Continued)

| Adjunct and insect (diluent attapulgite unless otherwise indicated) | Deposit of dust, micrograms per square centimeter | Extent of feeding | (A) | Mortality (percent) | | | | | Above or below 5 percent nicotine (A-B) | |
|---|---|-------------------------|-----|---------------------|---------------------|---------------------|--------------------------------------|-----------------------------|--|--|
| | | | | Mixture | Nicotine alone | | Adjunct alone 5 percent (D) | Additive effect (C+D) | | |
| | | | | | 5 percent (B) | 2 percent (C) | | | | |
| <i>Sesmin:</i> | | | | | | | | | | |
| Armyworm | 100 | Moderate | 35 | 88 | 32 | 14 | 46 | -53 | | |
| Beet armyworm | 200 | --do-- | 46 | 71 | 52 | 32 | 84 | -25 | | |
| Diamondback moth | 155 | --do-- | 70 | 100 | 50 | 23 | 73 | -30 | | |
| Green peach aphid | 170 | - | 26 | 90 | 37 | 9 | 46 | -64 | | |
| Melonworm | 110 | Moderate | 76 | 63 | 46 | - | - | +13 | | |
| Pea aphid | 100 | - | 97 | 82 | 81 | 0 | 81 | +15 | | |
| Southern armyworm | 115 | Trace | 85 | 92 | 80 | - | - | -7 | | |
| Variegated cutworm | 185 | Moderate | 3 | 23 | 7 | 3 | 10 | -20 | | |
| <i>2-Stilbazole:</i> | | | | | | | | | | |
| Armyworm | 100 | --do-- | 8 | 41 | 10 | 21 | 31 | -33 | | |
| Beet armyworm | 200 | Trace | 92 | 71 | 52 | 50 | 102 | +21 | | |
| Diamondback moth | 140 | Moderate | 0 | 75 | 23 | 0 | 23 | -75 | | |
| Green peach aphid | 200 | - | 64 | 89 | 23 | 8 | 31 | -25 | | |
| Melonworm | 180 | Moderate | 33 | 42 | 7 | - | - | -9 | | |
| Pea aphid | 100 | - | 94 | 82 | 81 | 8 | 89 | +12 | | |
| Southern armyworm (2) | 95 | Moderate | 88 | 85 | 46 | - | - | +3 | | |
| Variegated cutworm (2) | 233 | --do-- | 47 | 29 | 5 | 36 | 41 | +18 | | |
| <i>Tridecanenitrile: 4/</i> | | | | | | | | | | |
| Armyworm (3) | 102 | Moderate | 56 | 54 | 15 | - | - | + 2 | | |
| Diamondback moth | 95 | --do-- | 13 | 60 | 0 | - | - | -47 | | |
| Pea aphid (2) | 103 | - | 66 | 62 | 25 | - | - | + 4 | | |

4/ Related to phthalonitrile. Other footnotes on page 6.

Table 2. - Mortality data on (A) dust mixture containing 2 percent of nicotine and 5 percent of adjunct, (B) 3.5 percent of nicotine alone and (C) 2 percent of nicotine alone, and (D) 5 percent of adjunct alone, all applied against the pea aphid.

| Adjunct | Deposit of dusts, micrograms per square centimeter | (A) | (B) | Mortality (percent) | | | | | | |
|---|--|-----|-----|---------------------|----------------|--------------|-------------------------------|--------------------|---|-----|
| | | | | Mixture | Nicotine alone | | Adjunct alone 5 percent | Additive effect | Above or below 3.5 percent nicotine | |
| | | | | | 3.5 percent | 2 percent | | | (C) | (D) |
| γ -Acetyl- γ -(2-cyanoethyl)- pimelonitrile 1/ | 155 | 100 | 97 | 68 | - | - | - | - | + 3 | - 9 |
| p-Bromobenzenesulfonamide | 100 | 73 | 82 | 81 | 0 | 81 | - | - | + 6 | + 6 |
| 4-Caproylmorpholine | 100 | 100 | 94 | 11 | - | - | - | - | +20 | +20 |
| 4-Caprylylmorpholine | 105 | 76 | 56 | 5 | - | - | - | - | +14 | +14 |
| Cetyl ether | 100 | 96 | 82 | 81 | 0 | 81 | - | - | +29 | +29 |
| Bis-(2-cyanoethyl ether 1/ 2-Cyclohexylcyclohexylamine | 95 | 81 | 52 | 50 | - | - | - | - | + 6 | + 6 |
| 2,4-Dinitromesitylene | 120 | 73 | 86 | 16 | - | - | - | - | -13 | -13 |
| 1,4-Diphenylsemicarbazide | 100 | 80 | 77 | 46 | 13 | 59 | 93 | 152 | + 3 | + 3 |
| 1-Dodecanethiol | 105 | 21 | 86 | 46 | 2 | 48 | - | - | -65 | -65 |
| 3-Methyl-2,4-pentanediol | 95 | 96 | 80 | 16 | - | - | - | - | +16 | +16 |
| 2,3,4,5,6-Pentachloroanisole | 100 | 75 | 47 | 29 | - | - | - | - | +28 | +28 |
| Pentachlorocumene | 100 | 63 | 86 | 46 | 35 | 81 | - | - | -23 | -23 |
| Pentaerythritol diacetate | 100 | 32 | 83 | 17 2/ | 3 | 20 | - | - | -51 | -51 |
| Pentaerythritol diisobutyral | 100 | 98 | 82 | 81 | 0 | 81 | - | - | +16 | +16 |
| p-Phenylazoaniline | 100 | 69 | 82 | 81 | 0 | 81 | - | - | -13 | -13 |
| Phenyl sulfide | 100 | 100 | 86 | 46 | 0 | 46 | - | - | +14 | +14 |
| Phthalonitrile | 105 | 96 | 47 | 29 | 13 | 42 | - | - | +49 | +49 |
| Sesamin | 100 | 97 | 82 | 81 | 0 | 81 | - | - | +15 | +15 |
| 2-Stilbazole | 100 | 94 | 82 | 81 | 8 | 89 | - | - | +12 | +12 |
| Tridecanenitrile 1/ | 103 3/ | 66 | 62 | 25 | 2 | 27 | - | - | + 4 | + 4 |

1/ Related to phthalonitrile.

2/ 1 percent of nicotine.

3/ Average of 2 tests.

Table 3. - Adjuncts in mixture with nicotine showing promise of synergistic action against at least one species. (xx indicates apparent synergism, x no synergism, and - no test made.)

| Adjunct | Green peach aphid | Bean aphid | Pea aphid | Armyworm | Beet armyworm | Southern armyworm | Diamondback moth | Hawariian beet webworm | Melonworm | Large milkweed bug | Variiegated cutworm |
|---|-------------------|------------|-----------|----------|---------------|-------------------|------------------|------------------------|-----------|--------------------|---------------------|
| γ -Acetyl- γ -(2-cyanoethyl) pimelonitrile 1/ | - | - | xx | x | - | x | - | - | - | - | - |
| Bis(2-cyanoethyl) ether 1/ | - | - | xx | x | - | - | - | - | - | - | - |
| p-Bromobenzenesulfonamide | - | x | x | xx | - | xx | x | - | xx | - | xx |
| p-Bromo-N-isobutylbenzenesulfonamide | - | - | - | - | xx | - | - | x | - | - | - |
| (1)2,3-Butylene glycol | - | - | xx | x | - | x | - | - | - | - | - |
| 4-Caproyl morpholine | - | - | xx | x | - | x | - | - | - | - | - |
| 4-Caprylyl morpholine | - | - | xx | - | - | x | - | - | - | - | - |
| 6-Carbobutoxy-3,4-dihydro-2,2-dimethyl-4-oxo-1,2-pyran | - | - | - | - | - | xx | - | - | x | - | - |
| Cetyl ether | - | x | xx | x | x | xx | x | - | x | - | x |
| 1-(4-Chlorophenoxy) dodecane 2/ | - | - | - | - | - | xx | - | - | x | - | x |
| Bis(p-Chlorophenyl) sulfide in- | - | - | - | - | - | xx | - | xx | x | x | - |
| Pyrophyllite | - | - | - | - | - | xx | - | xx | x | - | - |
| Bentonite | - | - | - | - | - | xx | - | xx | x | - | - |
| Attapulgite | - | - | - | - | - | xx | - | xx | x | - | - |
| 2-Cyclohexylcyclohexylamine | - | - | xx | x | x | xx | x | - | - | - | x |
| 2,4-Dinitromesitylene | - | x | x | x | xx | xx | x | - | x | - | - |
| 2,4-Dinitrophenyl-2,3,4,5,6-pentachlorophenyl ether 2/ | - | - | x | - | - | xx | x | - | x | - | - |
| 1,4-Diphenylsemicarbazide | - | x | x | xx | - | xx | x | - | xx | - | xx |

1/ Related to phthalonitrile.

2/ Related to 2,3,4,5,6-pentachloroanisole.

Table 3 (Continued)

| Adjunct | Bean aphid | Green peach aphid | Pea aphid | Armyworm | Beet armyworm | Southern armyworm | Hawaiian beet webworm | Melonworm | Large milkweed bug | Cutworm | Variegated V |
|--|------------|-------------------|-----------|----------|---------------|-------------------|-----------------------|-----------|--------------------|---------|--------------|
| 1-Dodecanethiol | x | x | x | x | xx | - | - | - | - | - | - |
| Dodecyl acetoacetate in - | - | - | - | - | xx | - | - | - | - | - | - |
| Bentonite | - | - | - | - | xx | - | - | - | - | - | - |
| Pyrophyllite | - | - | - | - | x | - | - | - | - | - | - |
| Attapulgite | - | - | xx | xx | x | - | - | - | - | - | - |
| Tridecanenitrile 1/2 | - | - | - | - | xx | - | - | - | - | - | - |
| 2-(2-Methoxyethoxy)ethanol in - | - | - | - | - | xx | - | - | - | - | - | - |
| Bentonite | - | - | - | - | x | - | - | - | - | - | - |
| Pyrophyllite | - | - | - | - | xx | - | - | - | - | - | - |
| Attapulgite | - | - | - | - | x | - | - | - | - | - | - |
| 3-Methyl-2,4-pentanediol | - | - | - | - | x | - | - | - | - | - | - |
| 4'-Nitro-2-stilbazole | - | - | xx | - | xx | - | - | - | - | - | - |
| 2,3,4,5,6-Pentachloroanisole | x | x | xx | xx | x | - | - | - | - | - | - |
| Penta chlorocumene | - | - | - | - | xx | - | - | - | - | - | - |
| 1-(2,3,4,5,6-Pentachlorophenoxy)-octadecane 2/ | - | - | - | - | xx | - | - | - | - | - | - |
| 1-(2,3,4,5,6-Pentachlorophenoxy)-dodecane 2/ | - | - | - | - | xx | x | - | - | - | - | - |
| Pentaerythritol diacetal | x | x | xx | xx | x | - | - | - | - | - | - |
| Pentaerythritol diisobutyral | - | - | - | - | x | - | - | - | - | - | - |
| Phenyl ether | x | x | xx | xx | xx | - | - | - | - | - | - |
| Phenyl sulfide | - | x | xx | xx | - | xx | - | - | - | - | - |
| Phthalonitrile | - | - | - | xx | x | - | - | - | - | - | - |
| Polyacrylonitrile 1/2 | - | x | xx | x | x | - | - | - | - | - | - |
| Sesamin | x | x | xx | x | x | - | - | - | - | - | - |
| 2-Stillbazole | - | - | - | xx | x | - | - | - | - | - | - |
| 2,4,6-Trinitromesitylene | - | - | - | xx | x | - | - | - | - | - | - |
| s-Trithiane | - | - | - | xx | x | - | - | - | - | - | - |

Table 4. - Adjuncts in nicotine mixtures showing no evidence of synergistic action on insects against which they were tested. (x indicates that a test was made.)

| Adjunct | Pea aphid | Armyworm | Southern armyworm | Diamondback moth | Melonworm |
|--|-----------|----------|-------------------|------------------|-----------|
| Acetone semicarbazone | - | - | x | - | x |
| Acrylonitrile-dimethylbutadiene copolymer 1/ | x | x | - | - | - |
| p-Aminoacetanilide | - | - | x | - | x |
| Asarinin | - | - | x | - | x |
| α -Benzylidenequinaldine | - | - | x | - | x |
| 2,6-Bis(4-chlorostyryl)pyridine | - | - | x | - | x |
| Blackstrap molasses | - | - | x | - | x |
| Chlorinated paraffin | - | - | x | - | x |
| 4-Chloroanisole 2/ | - | - | x | - | x |
| α -Chlorobutyronitrile 1/ | x | x | - | - | - |
| β -Cyanoethyl acrylate 1/ | x | x | - | - | - |
| Decyl ether | - | - | x | - | x |
| Diazoaminobenzene | - | - | x | - | x |
| 3,4-Dibromopyrocatechol | - | - | x | - | x |
| α,α -Dibromo-2,4,6-trimethylacetophenone | - | - | x | - | x |
| 1,3-Dicyanoguanidine | x | - | - | x | - |
| Diethyl isopropylidenemalonate | x | x | - | x | - |
| N,N-Diethylauramide | x | - | - | x | - |
| 5,6-Dihydro-2,4,6-trimethyl-1,3,5-dithiazine | - | - | x | - | x |
| N,N-Dimethylcetylamine | - | - | x | - | x |
| Dimethyl α,β -dichlorosuccinate | x | x | - | x | - |
| 2,4-Dimethyl-3,5-dinitro-phenyl glyoxal monoxime | - | - | x | - | x |
| N,N-Dimethyldodecylamine oxide | - | - | x | - | x |
| 2,3-Dimethyl-1,4-naphthoquinone | - | - | x | - | x |
| 2,4-Dimethyl-3-pentanone semicarbazone | - | - | x | - | x |
| Dimethyl phthalate | - | - | x | - | x |
| 2,4-Dinitro-4'-hydroxydiphenylamine | - | - | x | - | x |
| 2,5-Dinitro-4-propyl-m-xylene | - | - | x | - | x |
| 1,5-Diphenyl-3-pentadieneone | - | - | x | - | x |
| 2,6-Distyrylpypyridine | - | - | x | - | x |

1/ Related to phthalonitrile.

2/ Related to 2,3,4,5,6-pentachloroanisole.

Table 4. - (Continued)

| Adjunct | Pea aphid | Armyworm | Southern armyworm | Diamondback moth | Melonworm |
|---|-----------|----------|-------------------|------------------|-----------|
| Dodecaethyleneglycol monolaurate | - | - | x | - | x |
| 3-Ethyl-5-(α -ethylpropenyl)-6-hydroxy-2-methyl-2,3-dihydrobenzofuran | - | - | x | - | x |
| 2-Ethyl-1,3-hexanediol | - | - | x | - | x |
| 2-Ethoxyethanol in- | | | | | |
| Bentonite | - | - | x | - | x |
| Pyrophyllite | - | - | x | - | x |
| Attapulgite | - | - | x | - | x |
| Hexachlorobenzene | x | - | - | x | - |
| 1-Hexadecanethiol | - | - | x | - | x |
| Hydracrylonitrile 1/ | x | x | - | - | - |
| 2-Hydroxyethanethiol | - | - | x | - | x |
| Bis(ω -Hydroxyethyl)sulfide | - | - | x | - | x |
| 8-Hydroxyquinoline | x | x | - | x | - |
| 4-Methylcyclohexanone semicarbazone | - | - | x | - | x |
| N-Methyl-2,2'-iminodiethanol | - | - | x | - | x |
| 2-Methyl-2,4-pentanediol | - | - | x | - | x |
| 10-Nitroanthrone | - | - | x | - | x |
| p-Nitrobenzenesulfonic acid | x | x | - | x | - |
| Bis(ω -Nitrophenyl)sulfide | x | x | - | x | - |
| Octadecyl ether | - | - | x | - | x |
| $\alpha,\alpha,2,4,6$ -Pentamethyl- $\alpha,3,5$ -tribromoacetophonone | - | - | x | - | x |
| Pentaerythritol soybean fatty acid monoester | - | - | x | - | x |
| 1,5 Pentanediol bis(phenylurethane) | x | x | - | x | - |
| 1,5-Pantanediol diacetate | x | x | - | x | - |
| Perthiocyanic acid | x | - | - | x | - |
| p-Phenyldazoaniline | x | x | x | x | x |
| p-Phenyldazoaniline hydrochloride | - | - | x | - | x |
| σ -Phenylphenol in - | | | | | |
| Bentonite | - | - | x | - | x |
| Pyrophyllite | - | - | x | - | x |
| Attapulgite | - | - | x | - | x |
| Phthalamide 1/ | x | x | - | x | - |
| Polylactic acid (115% lactic acid) in - | | | | | |
| Bentonite | - | - | x | - | x |
| Pyrophyllite | - | - | x | - | x |
| Attapulgite | - | - | x | - | x |
| Sodium ethyl methyl oleylamide sulfonate | - | - | x | - | x |

Table 4. - (Continued)

| Adjunct | Pea aphid | Armyworm | Southern armyworm | Diamondback moth | Melonworm |
|---|-----------|----------|-------------------|------------------|-----------|
| Sorbitol ester of dehydrated castor oil fatty acids | - | - | x | - | x |
| Sorbitol ester of linseed oil acids | - | - | x | - | x |
| Sulfonated castor oil (75%) | - | - | x | - | x |
| Tetrachlorocatechol | - | - | x | - | x |
| Tetrahydrofurfuryl oleate | - | - | x | - | x |
| Thiourea | x | - | - | x | - |
| Tribenzylamine | - | - | x | - | x |
| 2,4,6-Trichloroanisole 2/ | - | - | x | - | x |
| Tris(<i>p</i> -chlorophenyl)methane | - | - | x | - | x |
| Triethylaminomethylphenol | x | x | - | x | - |
| 2,4,6-Trimethylacetophenone | - | - | x | - | x |
| 2,4,6-Trinitro- <i>m</i> -xylene | - | - | x | - | x |
| Triphenylmethane | - | - | x | - | x |